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Enhancing Remote Operation of Electric Wheelchairs Using Omnidirectional Visible Light Communication: Overcoming Electromagnetic Interference in Medical Settings

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***Abstract*— Recent advancements in equipment have highlighted their role in enhancing nursing care and preventing the transmission of diseases like COVID-19, sparking interest in remotely operating electric wheelchairs. Most current electric wheelchairs use infrared or electromagnetic waves, risking interference with human bodies and sensitive devices. This study introduces a remote control system for electric wheelchairs using harmless omnidirectional visible light communication (OVLC) through a Light Emitting Diode (LED) array and an omnidirectional camera that captures signal patterns without needing precise alignment. However, challenges such as resolution loss and image distortion arise with the omnidirectional camera, impacting signal decoding accuracy. To address these, we developed an AI-based technique that accurately recognizes and decodes LED patterns from a distance, enabling successful remote control of an electric wheelchair with our novel visible light teleoperation system.**

I. INTRODUCTION

This study introduces a teleoperation system using a novel omnidirectional visible light communication (OVLC) designed for nursing and medical care sites. The proposed remote-control method involves pre-defining the lighting patterns of the LED array, with each pattern corresponding to a specific movement of the electric wheelchair, such as stopping, moving forward, backward, or turning. These lighting patterns are captured by the omnidirectional camera at the receiver end. The electric wheelchair then responds by moving according to the pre-defined lighting pattern detected. This communication protocol for remote control exclusively uses visible light and does not depend on radio waves or infrared-based communication. Visible light communication (VLC) systems primarily use either photodiodes, which convert light into current or voltage, or image sensors that capture visual patterns as images, each with their respective challenges in interference and operational range. Our study utilizes an omnidirectional camera as the receiver, overcoming the limited viewing angle of traditional two-dimensional cameras [1] and enabling remote control from all directions. Despite the complexity of managing multiple receivers with OVLC, this approach significantly enhances coverage. However, implementing such systems on wheelchairs is challenging due to space constraints and the processing power required for multiple cameras.

II. PROPOSED SYSTEM

We propose a simplified setup using a single omnidirectional camera, maintaining remote control capabilities even in environments with obstacles. Additionally, this paper introduces a reduced-size LED array as the transmitter, improving portability and user-friendliness.

Fig. 1 LED Array

We also present a novel AI-based method to overcome the image distortion and resolution reduction challenges posed by the omnidirectional camera, enhancing the system's ability to identify LED blinking patterns accurately.

At the receiver's end, we implemented machine learning using the YOLOv5 model, trained with specifically created omnidirectional image datasets of the transmitter lighting patterns, which are used to facilitate communication between the transmitter and receiver.

III. SYSTEM IMPLEMENTATION ON A REAL MACHINE

We successfully integrated the developed receiver system into a motorized wheelchair as shown in Fig. 1, using an edge computer and some related hardware, enabling effective detection of the LED array and identification of its lighting patterns for omnidirectional visible light communication (OVLC). This integration was crucial in achieving our objective of remote wheelchair control via visible light, allowing for omnidirectional maneuverability. Through this system, teleoperation was effective within a range of a few meters. Looking ahead, our future work will focus on extending the teleoperation distance by enhancing the LED array detection model.

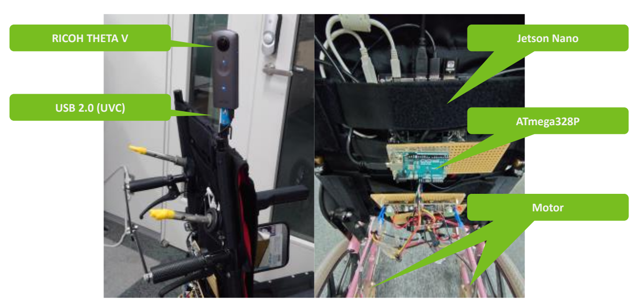

Fig. 2 System Implementation on a real wheelchair

REFERENCES

[1] M. Tsunoda and C. Premachandra, "Remote Control of a Wheeled Robot by Visible Light for Support in Infectious Disease Hospitals," in *IEEE Access*, Vol. 9, pp. 124165 - 124175, Sept. 2021.